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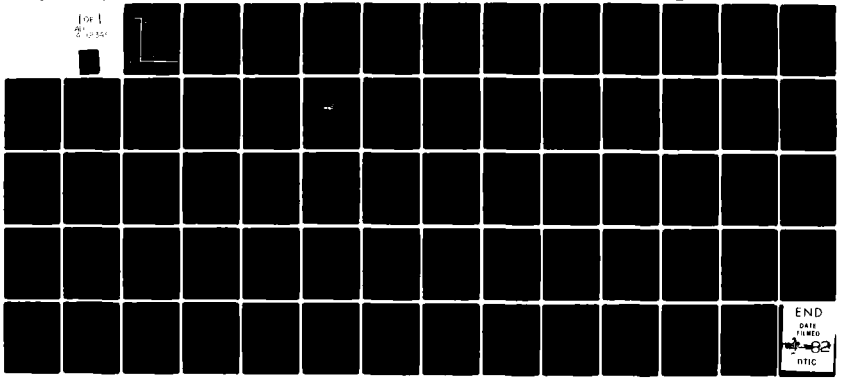
POLYSTYRENE CORRECTOR ELEMENT ADDED TO EXISTING POSITIVE ACRYTA--ETC(U)
FEB 82 A R TUCKER F33615-78-C-0048

UNCLASSIFIED AFHRL-TP-81-47 NL



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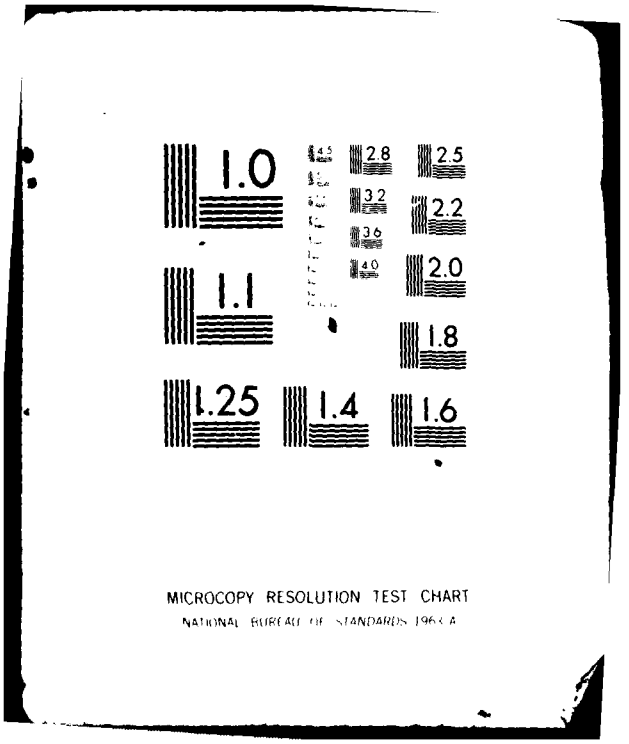
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AIR FORCE HUMAN RESOURCES LABORATORY

AD A112345

POLYSTYRENE CORRECTOR ELEMENT ADDED TO EXISTING POSITIVE ACRYTATE FOR SIMULATOR COLLIMATOR

By

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OPERATIONS TRAINING DIVISION
Williams Air Force Base, Arizona 85224

February 1982

Final Report

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

WELDON M. DUBE
Contract Monitor

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Operations Training Division

RICHARD C. NEEDHAM, Colonel, USAF
Chief, Operations Training Division

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binocular errors
chromatic angular errors
chromatic intercept differences
optics
polystyrene
Q ray/P ray
ray intercept heights
simulator collimator
visual simulation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

In an earlier study, Electronic Systems Products, Inc. designed and analyzed a polystyrene corrector lens for an existing polymethylmethacrytate positive aspheric element. The results showed that an optimum correction lens was feasible to correct the existing lens substantially, but the optimal solutions were too long and required too large a display screen to be useful. One of the recommendations of that study was to attempt a design that would fall between the optima and the uncorrected singlet and be a good compromise. Work according to this compromise has been completed, and this report describes the results.

The approach chosen was an aspheric polystyrene corrector between the observer and the old element. The focal length is 117 inches. The chromatic errors are approximately seven times better than the old singlet.

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Item 20 (Continued):

This collimator is to be used in a visual simulator to view a three-color image projected onto a screen. The singlet collimator by itself does an adequate job but results in color fringes that are noticeable. Some of these problems can be corrected by adjusting the magnification of each of the three color images, as they are projected, but the actual chromatic error achieved depends upon the position of the viewer's head. Thus, projection compensation is not entirely satisfactory. It was demonstrated in the earlier study that the chromatic error could be substantially removed using a negative corrector element, but the lens with optimum correction left the screen size and position too large. The goal of this program is to provide as much correction as possible within a restricted package size to allow adjoining displays.

AFHRL-TP-81-47 February 1982

POLYSTYRENE CORRECTOR ELEMENT ADDED TO EXISTING POSITIVE ACRYTATE FOR SIMULATOR COLLIMATOR

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Warren E. Richeson
Chief, Engineering Branch

PREFACE

The purpose of this effort was to develop a refractive optical display to provide an out-the-window scene for multi-crew cockpits. Parallel design studies sponsored by AFHRL have recently recommended a large off-axis spherical mirror as the imaging system most likely to meet the design goals stated. Because the technology to produce these large mirrors was untried and considered to be high risk, this effort investigated the use of lower risk, lower cost refractive optics to fulfill the need for multi-viewer infinity displays. The contract for this effort was awarded to Electronic Systems Products, Incorporated. This study was conducted for the Operations Training Division, Air Force Human Resources Laboratory, Air Force Systems Command. The study supports Project 1958, Training Simulation Technology Integration, Mr. Warren E. Richeson, Project Monitor; Task 1958-01, Advanced Visual Systems, Mr. Eric G. Monroe, Task Monitor; and Work Unit 1958-01-11, Refractive Optical Displays, Mr. Weldon M. Dube', Work Unit Monitor.

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1.0 INTRODUCTION

In an earlier study, Electronic Systems Products, Inc. designed and analyzed a polystyrene corrector lens for an existing polymethylmethacrytate positive aspheric element. The results showed that an optimum correction lens was feasible to correct the existing lens substantially, but the optimal solutions were too long and required too large a display screen to be useful. One of the recommendations of that report was to attempt a design that would fall between the optima and the uncorrected singlet and be a good compromise. Work according to this compromise has been completed, and this report describes the results.

The approach chosen was an aspheric polystyrene corrector between the observer and the old element. The focal length is 117 inches. The chromatic errors are approximately seven times better than the old singlet.

2.0 GOALS AND REQUIREMENTS

This collimator is to be used in a visual simulator to view a three-color image projected onto a screen. The singlet collimator by itself does an adequate job but results in color fringes that are noticeable. Some of this can be corrected by adjusting the magnification of each of the three color images, as they are projected, but the actual chromatic error achieved depends upon the position of the viewer's head. Thus, projection compensation is not entirely satisfactory. It was demonstrated in the earlier study, referenced in Section 1.0, that the chromatic error could be substantially removed using a negative corrector element, but the lens with optimum correction left the screen size and position too large. The goal of this program is to provide as much correction as possible within a restricted package size to allow adjoining displays.

Table 1 lists the goals and achievements of this project. All of the goals have been met, and the chromatic errors in the worst case have been reduced by as much as a factor of 7.

SUMMARY OF DESIGN GOALS AND RESULTS

	Parameter	Goal or Specification	Design
1.	Element Focal Length	104 to 120 inches	117 inches
2.	Image Distance	100 to 110 inches	110 inches
3.	Chromatic Differences (480 nm to 620 nm)	Not specified but should be less than 70% of present single element	Angular difference for worst case is 0.9191 vs. 6.34 for the singlet i.e., 14.5%
4.	Screen Radius	200 inches or greater	200 inches
5.	Maximum Corrector Blank Thickness	4.0 inches	3.438 (minimum thickness - sag plus Center Thickness)

TABLE 1

3.0 DESIGN DESCRIPTION AND ANALYSIS

The design consists of two elements, the existing acrylic element and a polystyrene corrector plate. The corrector plate is aspherized on both sides to the 10th order. Table 2 describes the design, showing the surface equation, element center thickness, airspaces, and clear apertures. Table 2 also provides a complete listing of surface coordinates for the corrector plate (in increments of 0.05 inch) used to manufacture the lens. Figure 1 illustrates the lens in cross-section. The pupil position is that for the P-rays described in Table 3. This table lists the four head or pupil positions used to design and analyze the lens.

The analysis was conducted differently than in the earlier study. A new metric analysis program developed as part of CODE V allows differences in configurations to be calculated as a function of input angle. This program was used to find differences at the two ends of the spectrum. These chromatic differences are shown for half of the front element diameter (because of planar symmetry) in Tables 4 through 11 for each of the head positions. The errors are converted to angular errors in viewing space. Note that the tables are displayed upside-down, i.e., positive elevation angles increase downward).

A similar analysis was performed on the single element, and the results are shown in Appendix I. Comparing results of the two analyses shows an improvement by a factor of from 3 to 7 for the chromatic errors. These same errors can be represented as intercept differences at the screen. They are presented in this form in Tables 12 through 19 for the corrected collimator.

MODEL DATA

7/12/79
MODIFIED DOUBLET COLLIMATOR LSP-DIS-002 1300

ELEMENT	R1	R2	T	CA1	CA2	GLASS
	OBJECT DISTANCE =		INFINITY			
			APERTURE STOP	2.500		
			0.0000			
	DECENTER (1)*1					
				40.0624		
			26.790*2			
1	A(1)	A(2)	1.5000	51.9432	52.9953	PLYST
			.4000			
2	A(3)	A(4)	10.1968	53.7420	55.6675	491.572
			116.3910*3			
	Defocussing =		-6.3910			
IMAGE	-200.0000			255.5452		

NOTE - POSITIVE RADIUS INDICATES THE CENTER OF CURVATURE IS TO THE RIGHT
NEGATIVE RADIUS INDICATES THE CENTER OF CURVATURE IS TO THE LEFT

- DIMENSIONS ARE GIVEN IN INCHES

ASPHERIC CONSTANTS

$$Z = \frac{(CURVE)^2}{1 + (1-(1+K)(CURV)^2 Y^2)^{.5}} + (A)Y^4 + (B)Y^6 + (C)Y^8 + (D)Y^{10}$$

ASPHERIC	CURV	K	A	B	C	D
A(1)	.00320391	0.000000	-3.54275E -6	2.22057E -9	3.69805E -13	-1.57559E -15
A(2)	.00756631	0.000000	-2.55995E -6	2.50841E -9	-2.75658E -12	1.05124E -15
A(3)	.00572633	2.216700	-2.13450E -7	-1.01360E -9	1.12410E -12	-3.72780E -17
A(4)	-.01619050	-2.503000	-2.12120E -6	4.66780E -9	-7.96500E -12	4.22520E -15

DECENTERING CONSTANTS

DECENTER	X	Y	Z	ALPHA	BETA	GAMMA
D(1)	0.0000	3.60000*1	0.00000	0.00000	0.00000	0.00000

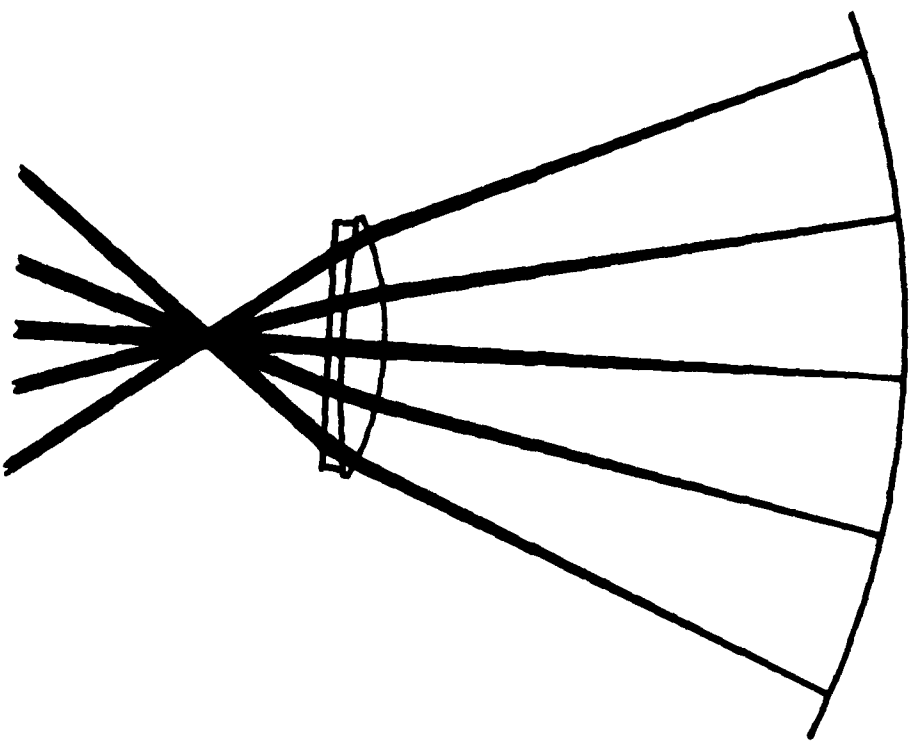
* ZOOM PARAMETERS		POS .1	POS .2	POS .3	POS .4
*1	=	3.6000	-3.6000	18.7812	18.5430
*2	=	26.7909	68.1909	38.0720	56.9851
*3	=	116.3910	116.3910	116.3910	116.3910

NOTE: THIS IS A DECENTERED SYSTEM. IF ELEMENTS WITH POWER ARE DECENTERED OR TILTED, THESE FIRST ORDER PROPERTIES ARE PROBABLY INADEQUATE IN DESCRIBING THE SYSTEM CHARACTERISTICS.

		POS.1	POS.2	POS.3	POS.4
EFL	=	117.0000	117.0000	117.0000	117.0000
BFL	=	116.3910	116.3910	116.3910	116.3910
FFL	=	-82.6137	-41.2137	-71.3326	-52.4195
F/NC	=	46.8000	46.8000	46.8000	46.8000
OAL	=	38.8877	80.2877	50.1688	69.0819
SEMI-FIELD ANGLE	=	34.0000	21.2500	8.8200	6.0500
ENTR PUPIL DIAMETER	=	2.5000	2.5000	2.5000	2.5000
DISTANCE	=	0.0000	0.0000	0.0000	
0.0000					
EXIT PUPIL DIAMETER	=	3.5406	7.0972	4.1005	5.5800
DISTANCE	=	-49.3079	-215.7560	-75.5129	-144.7524
AREP STOP DIAMETER	=	2.5000	2.5000	2.5000	2.5000

Table 2

MODIFIED DOUBLET COLLIMATOR



SCALE 0.025
Position 1
ORA 7/23/79

FIGURE 1

PUPIL LOCATION WITH RESPECT TO FRONT VERTEX

	P Rays	Q Rays	Position 1	Position 2
X Coordinate	- 3.6	3.6	-18.7812	-18.5430
Z Coordinate	-26.7909	-68.1909	-38.072	-56.9851
Range of Angles (degrees)	42.2 to -34	15.8 to -21.25	47.53 to -8.82	36.56 to -6.05

Table 3

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	1.8218	1.3517	.7816	.0413	-.7708	-1.5246	-2.1326
2.50	1.8248	1.3512	.7817	.0408	-.7723	-1.5243	-2.1378
5.00	1.8339	1.3496	.7818	.0391	-.7765	-1.5233	-2.1541
7.50	1.8500	1.3470	.7814	.0362	-.7831	-1.5215	-2.1835
10.00	1.8741	1.3436	.7800	.0319	-.7910	-1.5191	-2.2295
12.50	1.9079	1.3399	.7768	.0261	-.7995	-1.5164	-2.2979
15.00	1.9533	1.3369	.7712	.0188	-.8075	-1.5145	-2.3972
17.50	2.0117	1.3361	.7628	.0098	-.8142	-1.5158	-2.5416
20.00	2.0838	1.3401	.7520	-.0007	-.8196	-1.5239	-2.7615
22.50	2.1680	1.3526	.7398	-.0123	-.8243	-1.5450	-3.1572
25.00	2.2632	1.3787	.7282	-.0248	-.8303	-1.5875	
27.50		1.4243	.7206	-.0378	-.8415	-1.6635	
30.00		1.4954	.7216	-.0510	-.8635	-1.7892	
32.50		1.5944	.7369	-.0646	-.9050	-1.9890	
35.00		1.7175	.7723	-.0794	-.9773	-2.3544	
37.50			.8311	-.0975	-1.0951		
40.00			.9112	-.1240	-1.2994		
42.50							
45.00							
47.50							
50.00							

Table 4

CHROMATIC ANGULAR ERRORS - P RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.1170	-.1371	-.1576	-.1641	-.1671	-.1509	-.1262
5.00	-.2344	-.2732	-.3149	-.3287	-.3338	-.3000	-.2532
7.50	-.3527	-.4073	-.4711	-.4941	-.4995	-.4457	-.3823
10.00	-.4728	-.5384	.6251	.6593	-.6627	-.5862	-.5154
12.50	-.5958	-.6660	-.7751	-.8225	-.8209	-.7203	-.6555
15.00	-.7230	-.7896	-.9190	-.9806	-.9714	-.8474	-.8078
17.50	-.8563	-.9099	-1.0545	-1.1298	-1.1109	-.9681	-.9804
20.00	-.9968	-1.0284	-1.1800	-1.2665	-1.2371	-1.0850	-1.1903
22.50	-1.1449	-1.1485	-1.2954	-1.3883	-1.3498	-1.2036	-1.4901
25.00	-1.3009	-1.2756	-1.4029	-1.4954	-1.4518	-1.3330	
27.50		-1.4175	-1.5084	-1.5923	-1.5506	-1.4866	
30.00		-1.5826	-1.6223	-1.6889	-1.6594	-1.6825	
32.50		-1.7772	-1.7598	-1.8016	-1.7973	-1.9466	
35.00		-2.0014	-1.9396	-1.9533	-1.9911	-2.3678	
37.50			-2.1770	-2.1703	-2.2673		
40.00			-2.4828	-2.4745	-2.6960		
42.50							
45.00							
47.50							
50.00							

Table 5

CHROMATIC ANGULAR ERRORS - P RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	1.7350	1.2396	.8166	.0502	-.7218	-1.1892	-1.6513
2.50	1.7446	1.2257	.8077	.0505	-.7142	-1.1747	-1.6608
5.00	1.7667	1.1903	.7777	.5008	-.6875	-1.1367	-1.6882
7.50	1.7603	1.1536	.7244	.0502	-.6385	-1.0932	-1.7152
10.00	1.5963	1.1479	.6611	.0483	-.5783	-1.0748	-1.6507
12.50		1.1990	.6174	.0460	-.5343	-1.1119	
15.00		1.2252	.6248	.0448	-.5370	-1.1595	
17.50			.6598	.0455	-.5727	-.9191	
20.00				.0430			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 6

CHROMATIC ANGULAR ERRORS - Q RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.2415	-.2562	-.3294	-.3483	-.3328	-.2656	-.2424
5.00	-.4873	-.4955	-.6307	-.6813	-.6395	-.5124	-.4908
7.50	-.7237	-.7155	-.8729	-.9588	-.8883	-.7351	-.7430
10.00	-.8660	-.9411	-1.0488	-1.1446	-1.0678	-.9552	-.9453
12.50		-1.2165	-1.2076	-1.2692	-1.2232	-1.2198	
15.00		-1.4719	-1.4482	-1.4411	-1.4530	-1.5033	
17.50			-1.7597	-1.7584	-1.7716	-1.3736	
20.00				-1.7817			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 7

CHROMATIC ANGULAR ERRORS - Q RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	1.9634	1.5006	1.1151	.3823	-.6916	-1.7544	-2.3877
2.50	1.9589	1.4993	1.1091	.3786	-.6955	-1.7473	-2.4061
5.00	1.9435	1.4961	1.0909	.3666	-.7060	-1.7262	-2.4667
7.50	1.9110	1.4929	1.0610	.3449	-.7204	-1.6925	-2.5876
10.00	1.8498	1.4926	1.0207	.3124	-.7344	-1.6502	-2.8056
12.50	1.7428	1.4986	.9735	.2692	-.7447	-1.6087	-3.2075
15.00		1.5129	.9249	.2183	-.7501	-1.5832	-4.1947
17.50		1.5326	.8827	.1650	-.7533	-1.5959	
20.00		1.5408	.8554	.1154	-.7616	-1.6741	
22.50		1.4942	.8482	.0745	-.7865	-1.8384	
25.00		1.3212	.8530	.0433	-.8420	-2.0683	
27.50			.8265	.0139	-.9300		
30.00			.6772	-.0379	-1.0020		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 8

CHROMATIC ANGULAR ERRORS - POSITION 1 RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.1436	-.1595	-.1999	-.2354	-.2512	-.2171	-.1718
5.00	-.2849	-.3184	-.3956	-.4686	-.4990	-.4246	-.3511
7.50	-.4203	-.4769	-.5828	-.6948	-.7364	-.6139	-.5496
10.00	-.5430	-.6360	-.7579	-.9056	-.9520	-.7802	-.7871
12.50	-.6417	-.7979	-.9192	-1.0909	-1.1332	-.9257	-1.1052
15.00		-.9655	-1.0689	-1.2444	-1.2741	-1.0630	-1.6737
17.50		1.1388	-1.2146	-1.3693	-1.3825	-1.2173	
20.00		1.3068	-1.3696	-1.4816	-1.4831	-1.4243	
22.50		-1.4302	-1.5491	-1.6102	-1.6157	-1.7114	
25.00		-1.4282	-1.7522	-1.7883	-1.8220	-2.0343	
27.50			-1.9110	-2.0182	-2.0884		
30.00			-1.8335	-2.1631	-2.1996		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 9

CHROMATIC ANGULAR ERRORS - POSITION 1 RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	2.0694	1.3971	.9042	.0931	-.8870	-1.4696	-2.0653
2.50	2.0624	1.3909	.8942	.0902	-.8836	-1.4553	-2.0804
5.00	2.0305	1.3761	.8630	.0808	-.8697	-1.4170	-2.1201
7.50	1.9355	1.3638	.8106	.0632	-.8387	-1.3689	-2.1512
10.00	1.7102	1.3705	.7448	.0385	-.7915	-1.3367	-2.0775
12.50		1.4081	.6849	.0123	-.7419	-1.3536	
15.00		1.4474	.6557	-.0078	-.7136	-1.4351	
17.50		1.3352	.6740	-.0159	-.7297	-1.4629	
20.00			.6925	-.0147	-.7712		
22.50				-.0336			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 10

CHROMATIC ANGULAR ERRORS - POSITION 2 RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.50	28.30	35.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.2218	-.2283	-.2928	-.3201	-.3151	-.2383	-.2209
5.00	-.4360	-.4514	-.5689	-.6313	-.6116	-.4606	-.4487
7.50	-.6226	-.6697	-.8104	-.9094	-.8635	-.6604	-.6775
10.00	-.7353	-.8928	-1.0077	-1.1233	-1.0512	-.8504	-.8558
12.50		-1.1365	-1.1744	-1.2683	-1.1873	-1.0674	
15.00		-1.3869	-1.3555	-1.3901	-1.3301	-1.3488	
17.50		-1.4884	-1.6075	-1.5748	-1.5648	-1.5714	
20.00			-1.8645	-1.8712	-1.8636		
22.50				-1.9216			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 11

CHROMATIC ANGULAR ERRORS - POSITION 2 RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	.200504	.160841	.092917	.004847	-.087325	-.169611	-.212598
2.50	.200206	.160516	.091897	.004848	-.087210	-.169211	-.212186
5.00	.199326	.159541	.091528	.004851	-.086855	-.168008	-.210973
7.50	.197899	.159711	.090886	.004851	-.086232	-.165987	-.209027
10.00	.195981	.155622	.089930	.004842	-.085301	-.163134	-.206463
12.50	.193645	.152684	.088613	.004815	-.084010	-.159448	-.203425
15.00	.190967	.149127	.086887	.004761	-.082304	-.154958	-.200082
17.50	.188005	.145017	.084714	.004672	-.080138	-.149746	-.196609
20.00	.184755	.140470	.082077	.004542	-.077486	-.143963	-.193221
22.50	.181101	.135660	.079003	.004374	-.074360	-.137843	-.190507
25.00	.176781	.130813	.075572	.004176	-.070827	-.131696	
27.50		.126175	.071937	.003969	-.067016	-.125861	
30.00		.121939	.068322	.003793	-.063125	-.120603	
32.50		.118092	.064994	.003697	-.059389	-.115991	
35.00		.114237	.062187	.003740	-.056011	-.112139	
37.50			.059931	.003958	-.053046		
40.00			.057869	.004315	-.050430		
42.50							
45.00							
47.50							
50.00							

Table 12

CHROMATIC INTERCEPT DIFFERENCES - P RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.50	-.014882	-.017170	-.018667	-.019264	-.019728	-.019070	-.016356
5.00	-.029685	-.034197	-.037252	-.038494	-.039375	-.037940	-.032592
7.50	-.044338	-.050935	-.055658	-.057635	-.058836	-.056405	-.048607
10.00	-.058785	-.067230	-.073753	-.076585	-.077966	-.074245	-.064332
12.50	-.072989	-.082930	-.091364	-.095178	-.096558	-.091230	-.079745
15.00	-.086934	-.097892	-.108273	-.113178	-.114346	-.107171	-.094881
17.50	-.100615	-.111999	-.124223	-.130277	-.131012	-.121879	-.109828
20.00	-.114007	-.125194	-.138948	-.146118	-.146220	-.135295	-.124755
22.50	-.127008	-.137516	-.152216	-.160338	-.159677	-.147510	-.140164
25.00	-.139373	-.149125	-.163900	-.172651	-.171225	-.158828	
27.50		-.160312	-.174070	-.182955	-.180962	-.169761	
30.00		-.171416	-.183076	-.191468	-.189352	-.180912	
32.50		-.182592	-.191580	-.198837	-.197258	-.192695	
35.00		-.193417	-.200404	-.206110	-.205748	-.205552	
37.50			-.210030	-.214375	-.215494		
40.00			-.219802	-.223866	-.226344		
42.50							
45.00							
47.50							
50.00							

Table 13

CHROMATIC INTERCEPT DIFFERENCES - P RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	.205833	.163381	.096680	.005862	-.085629	-.156195	-.202771
2.50	.205129	.161782	.095991	.005805	-.085104	-.154770	-.202102
5.00	.203092	.157170	.093735	.005627	-.083342	-.150626	-.200285
7.50	.199401	.150296	.089572	.005311	-.079985	-.144359	-.197488
10.00	.191310	.142763	.083576	.004853	-.075031	-.137389	-.192291
12.50		.136514	.076833	.004273	-.069435	-.131697	
15.00		.131014	.071249	.003598	-.065038	-.127538	
17.50			.067421	.002825	-.062669	-.117336	
20.00				.001978			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 14

CHROMATIC INTERCEPT DIFFERENCES - Q RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.50	-.030154	-.034994	-.039722	-.040733	-.039761	-.035435	-.030574
5.00	-.059867	-.068151	-.077781	-.080376	-.077959	-.069074	-.060671
7.50	-.088555	-.098150	-.111968	-.116787	-.112441	-.099533	-.089912
10.00	-.113958	-.125068	-.140145	-.147012	-.141015	-.126672	-.117062
12.50		-.150788	-.162438	-.169606	-.163574	-.152240	
15.00		-.175610	-.183074	-.187881	-.184085	-.177458	
17.50			-.205719	-.208533	-.206687	-.191341	
20.00				-.224643			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 15

CHROMATIC INTERCEPT DIFFERENCES - Q RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	.240774	.193560	.135513	.042320	-.070219	-.177886	-.221717
2.50	.240325	.193126	.135096	.042291	-.069996	-.176980	-.220933
5.00	.238902	.191862	.133829	.042175	-.069300	-.174236	-.218719
7.50	.236258	.189882	.131687	.041887	-.068060	-.169608	-.215459
10.00	.231882	.187376	.128671	.041317	-.066187	-.163118	-.211708
12.50	.224831	.184591	.124862	.040364	-.063602	-.154989	-.208131
15.00		.181771	.120491	.039001	-.060282	-.145750	-.206237
17.50		.179017	.115977	.037340	-.056290	-.136238	
20.00		.175992	.111900	.035690	-.051786	-.127378	
22.50		.171370	.108832	.034548	-.046982	-.119623	
25.00		.161957	.106898	.034452	-.042042	-.112302	
27.50			.104904	.035562	-.036982		
30.00			.098859	.036791	-.031784		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 16

CHROMATIC INTERCEPT DIFFERENCES - POSITION 1 RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.50	-.017869	-.020471	-.024610	-.027643	-.029242	-.028381	-.022610
5.00	-.035560	-.040712	-.048820	-.055003	-.058177	-.056012	-.044938
7.50	-.052838	-.060522	-.072213	-.081683	-.086338	-.082102	-.066846
10.00	-.069332	-.079764	-.094358	-.107109	-.112998	-.105859	-.088432
12.50	-.084378	-.098385	-.114870	-.130537	-.137198	-.126680	-.110059
15.00		-.116414	-.133511	-.151201	-.157957	-.144478	-.132759
17.50		-.133868	-.150344	-.168594	-.174699	-.160036	
20.00		-.150481	-.165834	-.182854	-.187799	-.175014	
22.50		-.165043	-.180765	-.195070	-.198951	-.190990	
25.00		-.174131	-.195628	-.207094	-.210702	-.207031	
27.50			-.208952	-.220181	-.224113		
30.00			-.213929	-.231376	-.233739		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 17

CHROMATIC INTERCEPT DIFFERENCES - POSITION 1 RAYS

CODE V 7/24/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	.242617	.181224	.105537	.010288	-.095491	-.176445	-.213543
2.50	.242046	.180326	.105040	.010395	-.094912	-.174812	-.212732
5.00	.240082	.177792	.103453	.010661	-.093047	-.169996	-.210359
7.50	.235697	.174132	.100585	.010942	-.089608	-.162382	-.206247
10.00	.226147	.170218	.096443	.011088	-.084414	-.152975	-.198892
12.50		.167006	.091602	.011095	-.077723	-.143446	
15.00		.164477	.087374	.011279	-.070398	-.135244	
17.50		.159041	.085252	.012308	-.063547	-.126990	
20.00			.084838	.014709	-.057337		
22.50				.017213			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 18

CHROMATIC INTERCEPT DIFFERENCES - POSITION 2 RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
IMAGE ERRORS (INCHES)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.50	-.026848	-.030018	-.035193	-.037194	-.037361	-.033258	-.027285
5.00	-.053240	-.059178	-.069262	-.073644	-.073554	-.064887	-.054241
7.50	-.078376	-.086866	-.100886	-.108010	-.107121	-.093503	-.080458
10.00	-.100327	-.112970	-.128741	-.138289	-.135991	-.118559	-.104607
12.50		-.137940	-.152255	-.162675	-.158809	-.141124	
15.00		-.161924	-.172628	-.181333	-.176733	-.163506	
17.50		-.181422	-.192739	-.197766	-.194112	-.184724	
20.00			-.213073	-.216424	-.213737		
22.50				-.230928			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 19

CHROMATIC INTERCEPT DIFFERENCES - POSITION 2 RAYS

It is desirable to correct some of the chromatic error by matching the ray heights for each color to its corresponding angle (i.e., changing the magnification for each color so that the differences in image height on the screen correspond to the chromatic aberration differences for each angle). The amount of error is not only a function of look angle, but also pupil position. Tables 20 through 23 show the ray heights versus angle from the four pupil distances. The offset was removed from the pupil position so that the data are for an axially symmetrical point.

Finally, a calculation of the binocular errors was performed for each of the head positions. The results are shown in Tables 24 through 31. Convergence and divergence are horizontal errors. Divergence implies that one eye looks up slightly while the other looks down. In the cases shown, convergence is negative and divergence is positive. The largest binocular error is for the P-rays and is slightly over 6 milliradians convergent. A slight improvement can be made by increasing the distance to the screen, but of course, the screen must become larger.

The same types of errors are listed for the single element in the Appendix. The dominant error is divergence, which makes the images appear as though they were in back of the viewer's head. Actually, the angles are difficult to fuse if the errors are too large, because they are near the edge of the aperture.

RAY INTERCEPT HEIGHTS VERSUS VIEWING ANGLE

FROM P-RAY DISTANCE*

Wave Length →	480	520	620
Angle (Degrees)	Image Height	Image Height	Image Height
0.0000	0.000000	0.000000	0.000000
1.9000	3.712527	3.729595	3.758954
3.8000	7.421425	7.455523	7.514172
5.7000	11.123509	11.174556	11.262357
7.6000	14.816427	14.884304	15.001052
9.5000	18.498974	18.583524	18.728941
11.4000	22.171276	22.272299	22.446039
13.3000	25.834816	25.952070	26.153710
15.2000	29.492267	29.625463	29.854501
17.1000	33.147129	33.295928	33.551771
19.0000	36.803143	36.967148	37.249105
20.9000	40.463488	40.642240	40.949511
22.8000	44.129781	44.322754	44.654423
24.7000	47.800887	48.007487	48.362521
26.6000	51.471625	51.691197	52.068454
28.5000	55.131474	55.363313	55.761566
30.4000	58.763509	59.006882	59.424862
32.3000	62.343903	62.598085	63.034528
34.2000	65.842483	66.106782	66.560487
36.1000	69.224839	69.498610	69.968457
38.0000	72.456302	72.738904	73.223774

*Rays are traced from a point on the optical axis equal in distance to the P-ray pupil point, but not decentered.

Table 20

RAY INTERCEPT HEIGHTS VERSUS VIEWING ANGLE

FROM Q-RAY DISTANCE*

Wavelength →	480	520	620
Angle (Degrees)	Image Height	Image Height	Image Height
0.0000	0.000000	0.000000	0.000000
.9250	1.844345	1.852491	1.866507
1.8500	3.688552	3.704829	3.732832
2.7750	5.533107	5.557481	5.599414
3.7000	7.379643	7.412064	7.467839
4.6250	9.231300	9.271698	9.341192
5.5500	11.092821	11.141105	11.224159
6.4750	12.970356	13.026412	13.122825
7.4000	14.870915	14.934604	15.044133
8.3250	16.801494	16.872652	16.995010
9.2500	18.767902	18.846342	18.981199
10.1750	20.773379	20.858894	21.005889
11.1000	22.817170	22.909542	23.068295
12.0250	24.893277	24.992291	25.162423
12.9500	26.989700	27.095154	27.276312
13.8750	29.088539	29.200261	29.392147
14.8000	31.167410	31.285269	31.487653
15.7250	33.202646	33.326546	33.539263
16.6500	35.174748	35.304608	35.527511
17.5750	37.076584	37.212271	37.445127
18.5000	38.924753	39.065964	39.308243

*Rays are traced from a point on the optical axis equal in distance to the Q-ray pupil point, but not decentered.

Table 21

RAY INTERCEPT HEIGHTS VERSUS VIEWING ANGLE

FROM POSITION 1 PUPIL DISTANCE*

Wavelength →	480	520	620
Angle (Degrees)	Image Height	Image Height	Image Height
0.0000	0.000000	0.000000	0.000000
1.4085	2.767580	2.780167	2.801817
2.8170	5.533745	5.558895	5.602157
4.2255	8.297490	8.335158	8.399952
5.6340	11.058586	11.108704	11.194911
7.0425	13.817855	13.880331	13.987791
8.4510	16.577319	16.652035	16.780544
9.8595	19.340182	19.426996	19.576303
11.2680	22.110633	22.209373	22.379181
12.6765	24.893456	25.003920	25.193874
14.0850	27.693440	27.815392	28.025080
15.4935	30.514616	30.647785	30.876733
16.9020	33.359357	33.503436	33.751111
18.3105	36.227401	36.382052	36.647862
19.7190	39.114898	39.279755	39.563065
21.1275	42.013624	42.188307	42.488451
22.5360	44.910568	45.094692	45.411003
23.9445	47.788154	47.981349	48.313185
25.3530	50.625454	50.827378	51.174142
26.7615	53.400764	53.611104	53.972253
28.1700	56.095981	56.314432	56.689437

*Rays are traced from a point on the optical axis equal in distance to the Position 1 pupil, but not decentered.

Table 22

RAY INTERCEPT HEIGHTS VERSUS VIEWING ANGLE

FROM POSITION 2 PUPIL DISTANCE*

Wave Length →	480	520	620
Angle (Degrees)	Image Height	Image Height	Image Height
0.0000	0.000000	0.000000	0.000000
1.0655	2.113019	2.122454	2.138686
2.1310	4.225655	4.244507	4.276939
3.1965	6.338092	6.366325	6.414896
4.2620	8.451573	8.489133	8.553746
5.3275	10.568736	10.615547	10.696070
6.3930	12.693728	12.749693	12.845959
7.4585	14.832064	14.897064	15.008859
8.5240	16.990179	17.064067	17.191136
9.5895	19.174687	19.257289	19.399329
10.6550	21.391361	21.482478	21.639139
11.7205	23.643918	23.743326	23.914216
12.7860	25.932710	26.040167	26.224864
13.8515	28.253516	28.368770	28.566835
14.9170	30.596656	30.719462	30.930463
15.9825	32.946777	33.076905	33.300446
17.0480	35.283648	35.420903	35.656640
18.1135	37.584436	37.728657	37.976311
19.1790	39.827871	39.978922	40.238257
20.2445	42.000779	42.158509	42.429262
21.3100	44.107390	44.271545	44.553269

*Rays are traced from a point on the optical axis equal in distance to the Position 2 pupil, but not decentered.

Table 23

CODE V 7/23/79

MODIFIED DOUBLET COLLIMATOR

POSITION 2 - POSITION 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	-4.1991	-6.0700	-2.2395	-.7514	-.2940	-3.1853	-5.2746
2.50	-4.1556	-6.0743	-2.2634	-.7516	-.3089	-3.2187	-5.2166
5.00	-4.0267	-6.0847	-2.3344	-.7547	-.3553	-3.3154	-5.0397
7.50	-3.8177	-6.0934	-2.4510	-.7680	-.4380	-3.4658	-4.7358
10.00	-3.5405	-6.0883	-2.6097	-.8028	-.5636	-3.6539	-4.2923
12.50	-3.2175	-6.0528	-2.8055	-.8727	-.7396	-3.8580	-3.6927
15.00	-2.9881	-5.9673	-3.0306	-.9920	-.9718	-4.0517	-2.9174
17.50	-2.6155	-5.8105	-3.2747	-1.1730	-1.2624	-4.2050	-1.9396
20.00	-2.4883	-5.5608	-3.5239	-1.4237	-1.6081	-4.2856	-.7020
22.50		-5.2009	-3.7599	-1.7447	-1.9974	-4.2601	.9999
25.00		-4.7251	-3.9605	-2.1266	-2.4092	-4.0959	
27.50		-4.1535	-4.0980	-2.5473	-2.8110	-3.7632	
30.00		-3.5584	-4.1421	-2.9710	-3.1600	-3.2402	
32.50		-3.0945	-4.0676	-3.3491	-3.4052	-2.5110	
35.00		-2.9566	-3.8734	-3.6256	-3.4961	-1.4410	
37.50			-3.6202	-3.7521	-3.3943		
40.00			-3.4417	-3.7137	-3.0501		
42.50							
45.00							
47.50							
50.00							

TABLE 24

BINOCULAR ERRORS - P RAYS

MODIFIED DOUBLET COLLIMATOR

POSITION 2 - POSITION 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.0012	.3006	.1601	.0438	.0017	-.2637	-.1266
5.00	-.0180	.5938	.3341	.0935	-.0127	-.5306	-.2240
7.50	-.0643	.8700	.5323	.1543	-.0560	-.7992	-.2632
10.00	-.1505	1.1158	.7585	.2297	-.1349	-1.0598	-.2159
12.50	-.2797	1.3127	1.0074	.3207	-.2476	-1.2925	-.0553
15.00	-.4433	1.4376	1.2637	.4248	-.3824	-1.4679	.2425
17.50	-.6152	1.4639	1.5021	.5358	-.5187	-1.5503	.6989
20.00	-.7473	1.3647	1.6897	.6434	-.6296	-1.5034	1.3422
22.50		1.1184	1.7891	.7344	-.6867	-1.2965	2.2672
25.00		.7175	1.7636	.7937	-.6653	-.9113	
27.50		.1849	1.5823	.8060	-.5496	-.3473	
30.00		-.4006	1.2282	.7578	-.3366	.3734	
32.50		-.8749	.7108	.6401	-.0374	1.2111	
35.00		-1.0392	.0929	.4548	.3219	2.2390	
37.50			-.4646	.2319	.7078		
40.00			-.7283	.0646	1.1702		
42.50							
45.00							
47.50							
50.00							

TABLE 25

BINOCULAR ERRORS - P RAYS

MODIFIED DOUBLET COLLIMATOR

POSITION 2 - POSITION 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	- 3.00	2.70	8.30	14.00
0.00	-2.0714	-5.4368	-2.3253	-1.1765	-1.3574	-4.1093	-3.6068
2.50	-2.0633	-5.3845	-2.4356	-1.1898	-1.4360	-4.1596	-3.4070
5.00	-2.2599	-5.1785	-2.7334	-1.2783	-1.6813	-4.2468	-2.8400
7.50	-3.2985	-4.6978	-3.1249	-1.5462	-2.0929	-4.2159	-2.0875
10.00		-3.8419	-3.4739	-2.0476	-2.6043	-3.9003	-1.8170
12.50		-2.8518	-3.6066	-2.6779	-3.0478	-3.2231	
15.00		-3.0620	-3.3635	-3.1603	-3.1905	-2.5053	
17.50			-3.0497	-3.2239	-2.9800	-3.3404	
20.00				-3.1109			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

TABLE 26

BINOCULAR ERRORS - Q RAYS

CODE V 7/23/79

MODIFIED DOUBLET COLLIMATOR

POSITION 2 - POSITION 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	- 3.00	2.70	8.30	14.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.1764	.5125	.3263	.0254	-.1240	-.5256	-.0643
5.00	-.2924	.8731	.7268	.0937	-.3638	-.9844	.0494
7.50	-.0181	.8879	1.1176	.2012	-.6884	-1.2090	.4089
10.00		.3765	1.2610	.2856	-.8905	-.9731	.6667
12.50		-.4857	.9276	.2815	-.7421	-.1691	
15.00		-.2145	.0998	.1790	-.1694	.7438	
17.50			-.3683	.0460	.4729	-.5575	
20.00				.1532			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 27

BINOCULAR ERRORS - Q RAYS

CODE V 7/23/79

MODIFIED DOUBLET COLLIMATOR

POSITION 2 - POSITION 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) - 8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00		.6441	1.5544	4.7655	4.8357	.1447	-4.0780
2.50		.7261	1.5180	4.7357	4.8139	.0538	-3.9097
5.00		.9736	1.4201	4.6401	4.7355	-.1992	-3.3937
7.50		1.3869	1.2931	4.4638	4.5668	-.5589	-2.4961
10.00		1.9506	1.1862	4.1917	4.2671	-.9441	-1.1573
12.50		2.6058	1.1585	3.8201	3.8084	-1.2625	.7432
15.00		3.2014	1.2720	3.3669	3.1968	-1.4238	3.6706
17.50		3.4302	1.5798	2.8796	2.4864	-1.3471	
20.00		2.7999	2.0987	2.4381	1.7816	-.9716	
22.50			2.7374	2.1434	1.2191	-.3030	
25.00			3.1481	2.0738	.9255	.4989	
27.50			2.6216	2.1758	.9444		
30.00				2.1021	1.1397		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 28

BINOCULAR ERRORS - POSITION 1 RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50		.2092	.3873	.0735	-.0390	-.4867	-.1903
5.00		.3699	.7780	.1874	-.1117	-.9822	-.2851
7.50		.4359	1.1581	.3664	-.2356	-1.4623	-.1929
10.00		.3701	1.4852	.6061	-.4000	-1.8569	.1705
12.50		.1653	1.6879	.8643	-.5663	-2.0670	.8869
15.00		-.1151	1.6762	1.0658	-.6859	-2.0048	2.1437
17.50		-.2680	1.3657	1.1192	-.7277	-1.6332	
20.00		.1134	.7216	.9380	-.6999	-.9887	
22.50			-.1393	.4642	-.6534	-.2145	
25.00			-.7339	-.2669	-.6578	.3726	
27.50			-.0164	-.9144	-.7137		
30.00				-.4822	-.5093		
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 29

BINOCULAR ERRORS - POSITION 1 RAYS

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00		-.6515	1.0586	1.9903	.8684	-4.1760	-3.5743
2.50		-.5222	.9610	1.9694	.7939	-4.2210	-3.3799
5.00		-.1074	.6989	1.8726	.5584	-4.3056	-2.8517
7.50		.6478	.3603	1.6225	.1460	-4.3061	-2.2270
10.00		1.7266	.0755	1.1640	-.4223	-4.0863	-2.1550
12.50		2.7703	.0030	.5376	-1.0514	-3.5540	
15.00		2.6151	.3027	-.0813	-1.5619	-2.7600	
17.50			.9542	-.4260	-1.7480	-2.2744	
20.00			1.1106	-.3444	-1.5834		
22.50				-.3167			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 30

BINOCULAR ERRORS - POSITION 2 RAYS

CODE V 7/23/79

MODIFIED DOUBLET COLLIMATOR

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50		.2714	.2770	-.0623	-.2119	-.6588	.0048
5.00		.4035	.6052	-.0668	-.5184	-1.2456	.1277
7.50		.2486	.9400	.0072	-.9124	-1.6284	.3786
10.00		-.2965	1.1123	.1101	-1.2553	-1.6412	.4438
12.50		-1.0640	.8872	.1257	-1.3787	-1.1881	
15.00		-1.1015	.0779	-.0808	-1.2278	-.3970	
17.50			-1.1697	-.6122	-.9175	-.0699	
20.00			-1.3945	-1.3070	-.7802		
22.50				-.8494			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table 31

BINOCULAR ERRORS - POSITION 2 RAYS

4.0 CONCLUSIONS

A polystyrene corrector has been designed for an acrylic aspheric collimator that reduces the maximum chromatic errors by a factor of seven. Other solutions that utilize the singlet, and provide even better chromatic correction, are unacceptable due to the requirement for an excessively large screen.

The screen is curved and both the focal length and back focal distance are longer (117 and 110 inches respectively) than for the single element alone.

APPENDIX I

Singlet Chromatic and Binocular

Errors Reference

SINGLET REFERENCE

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	4.8458	2.6022	1.2967	.0983	-1.1973	-2.8851	-6.7697
2.50	4.8689	2.6080	1.2995	.0977	-1.2021	-2.8939	-6.8218
5.00	4.9397	2.6257	1.3080	.0959	-1.2167	-2.9204	-6.9840
7.50	5.0637	2.6559	1.3219	.0926	-1.2407	-2.9659	-7.2769
10.00	5.2504	2.7001	1.3407	.0876	-1.2740	-3.0326	-7.7430
12.50	5.5162	2.7609	1.3642	.0806	-1.3166	-3.1245	-8.4652
15.00	5.8871	2.8423	1.3922	.0712	-1.3689	-3.2483	-9.6190
17.50	6.4076	2.9508	1.4256	.0591	-1.4321	-3.4152	-11.6401
20.00	7.1589	3.0968	1.4660	.0438	-1.5090	-3.6437	-15.9794
22.50	8.3109	3.2963	1.5168	.0248	-1.6050	-3.9642	
25.00		3.5752	1.5843	.0014	-1.7295	-4.4303	
27.50		3.9764	1.6787	-.0274	-1.8988	-5.1451	
30.00		4.5796	1.8174	-.0637	-2.1415	-6.3510	
32.50		5.5634	2.0303	-.1114	-2.5110	-8.8639	
35.00		7.4866	2.3754	-.1785	-3.1242		
37.50			2.9986	-.2851	-4.3455		
40.00			4.5087	-.5054			
42.50							
45.00							
47.50							
50.00							

Table A1

CHROMATIC ANGULAR ERRORS - P RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.3085	-.2594	-.2541	-.2528	-.2680	-.2909	-.4043
5.00	-.6241	-.5209	-.5108	-.5092	-.5390	-.5842	-.8241
7.50	-.9548	-.7870	-.7724	-.7724	-.8156	-.8824	-1.2782
10.00	-1.3108	-1.0605	-1.0409	-1.0450	-1.0999	-1.1885	-1.7940
12.50	-1.7057	-1.3450	-1.3180	-1.3284	-1.3935	-1.5071	-2.4180
15.00	-2.1601	-1.6457	-1.6052	-1.6234	-1.6976	-1.8449	-3.2413
17.50	-2.7063	-1.9707	-1.9052	-1.9308	-2.0145	-2.2129	-4.4837
20.00	-3.4022	-2.3323	-2.2222	-2.2521	-2.3486	-2.6292	-6.8662
22.50	-4.3656	-2.7501	-2.5645	-2.5922	-2.7090	-3.1252	
25.00		-3.2561	-2.9472	-2.9621	-3.1135	-3.7562	
27.50		-3.9047	-3.3973	-3.3834	-3.5949	-4.6288	
30.00		-4.7965	-3.9616	-3.8960	-4.2125	-5.9920	
32.50		-6.1564	-4.7243	-4.5723	-5.0781	-8.6725	
35.00		-8.6866	-5.8517	-5.5509	-6.4351		
37.50			-7.7649	-7.1467	-9.0301		
40.00			-12.2345	-10.4481			
42.50							
45.00							
47.50							
50.00							

Table A2

CHROMATIC ANGULAR ERRORS - P RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	5.6180	2.6726	1.3779	.0632	-1.2380	-2.5170	-4.8619
2.50	5.7746	2.6802	1.3827	.0640	-1.2432	-2.5209	-4.9738
5.00	6.3030	2.7131	1.3914	.0659	-1.2528	-2.5402	-5.3542
7.50	7.3891	2.8107	1.3962	.0677	-1.2571	-2.6051	-6.1504
10.00	9.2329	3.0681	1.4090	.0692	-1.2636	-2.7932	-7.5941
12.50		3.6965	1.4843	.0720	-1.3183	-3.2772	
15.00		5.1305	1.7463	.0801	-1.5293	-4.4194	
17.50			2.4689	.1002	-2.1356	-6.3382	
20.00				.1397			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A3

CHROMATIC ANGULAR ERRORS - Q RAYS

SINGLET REFERENCE

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.8056	-.5668	-.5722	-.5586	-.5697	-.5629	-.7192
5.00	-1.7528	-1.1430	-1.1468	-1.1379	-1.1442	-1.1302	-1.5420
7.50	-3.0653	-1.7647	-1.7142	-1.7240	-1.7124	-1.7281	-2.6383
10.00	-5.0664	-2.5461	-2.2841	-2.2882	-2.2766	-2.4486	-4.3002
12.50		-3.7946	-2.9714	-2.8834	-2.9376	-3.5477	
15.00		-6.2456	-4.1401	-3.7789	-4.0297	-5.6491	
17.50			-6.7439	-5.7194	-6.4294	-9.2704	
20.00				-10.1625			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A4

CHROMATIC ANGULAR ERRORS - Q RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	6.4636	3.5325	2.2439	.7835	-1.0150	-3.5529	-12.1803
2.50	6.5034	3.5416	2.2426	.7812	-1.0260	-3.5665	-12.5587
5.00	6.6228	3.5707	2.2385	.7735	-1.0582	-3.6084	-13.8926
7.50	6.8213	3.6253	2.2310	.7576	-1.1094	-3.6846	-17.1167
10.00	7.0920	3.7156	2.2209	.7303	-1.1770	-3.8099	-26.7017
12.50	7.4090	3.8579	2.2119	.6889	-1.2604	-4.0164	-162.5977
15.00		4.0764	2.2125	.6330	-1.3639	-4.3692	
17.50		4.4043	2.2381	.5650	-1.5018	-5.0005	
20.00		4.8801	2.3135	.4892	-1.7044	-6.2194	
22.50		5.5243	2.4759	.4104	-2.0329	-9.0438	
25.00		6.2488	2.7773	.3295	-2.6184		
27.50			3.2694	.2352	-3.8138		
30.00				.0581			
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A5

CHROMATIC ANGULAR ERRORS - POSITION 1 RAYS

SINGLET REFERENCE

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.4444	-.3461	-.3637	-.3848	-.4168	-.4559	-.8662
5.00	-.9043	-.6985	-.7288	-.7763	-.8404	-.9132	-1.9049
7.50	-1.3947	-1.0651	-1.0966	-1.1777	-1.2738	-1.3753	-3.4841
10.00	-1.9292	-1.4579	-1.4693	-1.5874	-1.7142	-1.8524	-7.1303
12.50	-2.5130	-1.8956	-1.8522	-2.0011	-2.1567	-2.3707	-52.8646
15.00		-2.4074	-2.2588	-2.4185	-2.6040	-2.9906	
17.50		-3.0379	-2.7169	-2.8543	-3.0824	-3.8447	
20.00		-3.8485	-3.2795	-3.3523	-3.6621	-5.2490	
22.50		-4.9019	-4.0398	-4.0050	-4.4928	-8.2138	
25.00		-6.1777	-5.1526	-4.9890	-5.8905		
27.50			-6.8394	-6.6386	-8.6437		
30.00				-9.6030			
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A6

CHROMATIC ANGULAR ERRORS - POSITION 1 RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

HORIZONTAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	7.5762	3.3312	1.7555	.2563	-1.4138	-3.1962	-9.1775
2.50	7.7249	3.3431	1.7566	.2557	-1.4222	-3.2070	-9.5395
5.00	8.1878	3.3872	1.7567	.2523	-1.4431	-3.2475	-10.8338
7.50	8.9855	3.4925	1.7502	.2433	-1.4676	-3.3484	-14.0371
10.00	9.9759	3.7203	1.7415	.2259	-1.4958	-3.5822	
12.50		4.1878	1.7581	.2012	-1.5517	-4.1077	
15.00		5.1010	1.8639	.1768	-1.6968	-5.3008	
17.50		6.6401	2.1834	.1678	-2.0597	-8.2657	
20.00			2.9466	.2037	-2.9375		
22.50				.3147			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A7

CHROMATIC ANGULAR ERRORS - POSITION 2 RAYS

SINGLET REFERENCE

Position 2 - Position 1

VERTICAL CHROMATIC DIFFERENCES
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.7799	-.5101	-.5246	-.5223	-.5435	-.5475	-1.0233
5.00	-1.6464	-1.0324	-1.0503	-1.0609	-1.0924	-1.1021	-2.3162
7.50	-2.6912	-1.5930	-1.5727	-1.6117	-1.6400	-1.6875	-4.4714
10.00	-3.9457	-2.2529	-2.0932	-2.1525	-2.1794	-2.3763	
12.50		-3.1459	-2.6524	-2.6852	-2.7475	-3.3581	
15.00		-4.5395	-3.3822	-3.3036	-3.4953	-5.1301	
17.50		-6.7676	-4.5987	-4.2799	-4.8181	-9.1844	
20.00			-6.9623	-6.2581	-7.7114		
22.50				-10.3871			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A8

CHROMATIC ANGULAR ERRORS - POSITION 2 RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	8.3893	-.2648	.5717	.7677	2.1635	3.0489	9.2104
2.50	8.5234	-.2425	.5765	.7954	2.1788	3.0494	9.3497
5.00	8.9327	-.1725	.5917	.8766	2.2233	3.0540	9.7804
7.50	9.6	-.0452	.6187	1.0050	2.2937	3.0726	10.5432
10.00	10.	.1553	.6609	1.1718	2.3856	3.1217	11.7176
12.50	12. 07	.4517	.7241	1.3659	2.4945	3.2247	13.4475
15.00	14.1432	.8738	.8173	1.5767	2.6182	3.4125	16.0053
17.50	16.9088	1.4595	.9539	1.7959	2.7582	3.7241	19.9675
20.00		2.2568	1.1527	2.0200	2.9223	4.2089	26.7875
22.50		3.3272	1.4398	2.2532	3.1263	4.9313	
25.00		4.7540	1.8507	2.5101	3.3973	5.9824	
27.50		6.6644	2.4330	2.8180	3.7761	7.5137	
30.00		9.3012	3.2516	3.2201	4.3213	9.8474	
32.50		13.2898	4.3978	3.7771	5.1177	13.9408	
35.00			6.0184	4.5702	6.3027		
37.50			8.4487	5.7069	8.1909		
40.00				7.3510			
42.50							
45.00							
47.50							
50.00							

Table A9

BINOCULAR ERRORS - P RAYS

SINGLET REFERENCE

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -30.00	-18.30	-6.70	5.00	16.70	28.30	40.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-.3221	.1148	.0236	.0077	.0736	-.0696	.2010
5.00	-.6780	.2245	.0612	.0199	.1315	-.1456	.4451
7.50	-1.1048	.3214	.1239	.0409	.1608	-.2299	.7817
10.00	-1.6458	.3932	.2172	.0738	.1539	-.3169	1.2739
12.50	-2.3577	.4210	.3384	.1200	.1104	-.3904	2.0142
15.00	-3.3243	.3783	.4756	.1785	.0389	-.4230	3.1594
17.50	-4.6879	.2295	.6068	.2452	-.0433	-.3760	5.0259
20.00		-.0702	.7006	.3126	-.1121	-.2009	8.4072
22.50		-.5779	.7173	.3694	-.1389	.1615	
25.00		-1.3684	.6099	.4008	-.0944	.7879	
27.50		-2.5554	.3242	.3885	.0500	1.8027	
30.00		-4.3656	-.2052	.3099	.3230	3.4893	
32.50		-7.4274	-1.0692	.1361	.7656	6.7810	
35.00			-2.4448	-.1747	1.4823		
37.50			-4.8792	-.7029	2.8925		
40.00				-1.7184			
42.50							
45.00							
47.50							
50.00							

Table A10

BINOCULAR ERRORS - P RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	16.9065	-.0086	.4677	.0860	.5980	.3899	4.4051
2.50	17.8959	.0965	.4254	.1550	.6077	.3699	4.7999
5.00	20.8312	.4959	.3206	.3180	.6184	.3744	6.0760
7.50		1.4439	.2304	.4736	.6042	.5848	8.5097
10.00		3.4020	.3053	.5473	.5978	1.2765	12.5165
12.50		7.1163	.8004	.5979	.7539	2.8243	
15.00		12.8690	2.1571	.8875	1.3870	5.7460	
17.50			4.9872	1.9464	2.9399	10.1305	
20.00				3.8191			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A11

BINOCULAR ERRORS - Q RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -20.00	-14.30	-8.70	-3.00	2.70	8.30	14.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-2.0242	.0818	-.0080	-.0261	.1350	-.0789	.5337
5.00	-4.6871	.0270	.0996	-.0074	.1475	-.1631	1.3993
7.50		-.4271	.2917	.0681	.0188	-.1175	3.0327
10.00		-1.7860	.3322	.1551	-.0943	.3844	6.0539
12.50		-4.9470	-.1697	.1717	.0979	1.8558	
15.00		-10.5843	-1.7771	.0426	.9474	5.0957	
17.50			-5.3395	-.3208	2.9837	10.5306	
20.00				-.9421			
22.50							
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A12

BINOCULAR ERRORS - Q RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00		11.2516	9.3379	10.2647	10.1756	9.6365	18.7438
2.50		11.4204	9.3236	10.2903	10.2122	9.5981	19.3653
5.00		11.9442	9.2933	10.3575	10.3101	9.5027	21.4210
7.50		12.8745	9.2840	10.4428	10.4375	9.4092	25.6626
10.00		14.2926	9.3577	10.5195	10.5548	9.4122	34.3600
12.50		16.2985	9.5999	10.5735	10.6324	9.6388	56.8627
15.00		18.9772	10.1217	10.6194	10.6705	10.2530	
17.50		22.3054	11.0648	10.7136	10.7178	11.4871	
20.00		25.9179	12.6058	10.9645	10.8829	13.7606	
22.50			14.9425	11.5360	11.3368	18.1995	
25.00			18.1859	12.6385	12.3063		
27.50			21.9332	14.4765	14.0982		
30.00				17.0557			
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A13

BINOCULAR ERRORS - POSITION 1 RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -8.00	.83	9.70	18.50	27.30	36.20	45.00
0.00		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50		-.1434	.0624	-.1626	-.0313	-.2278	.5294
5.00		-.3594	.1430	-.2853	-.1040	-.4861	1.3298
7.50		-.7306	.2399	-.3382	-.2434	-.7717	2.8256
10.00		-1.3575	.3156	-.3133	-.4454	-1.0258	6.0223
12.50		-2.3598	.2881	-.2370	-.6733	-1.1329	14.8299
15.00		-3.8613	.0296	-.1765	-.8709	-.9349	
17.50		-5.9274	-.6326	-.2378	-.9894	-.2311	
20.00		-8.3825	-1.9169	-.5615	-1.0131	1.3136	
22.50			-4.0758	-1.3320	-.9696	4.6866	
25.00			-7.2828	-2.8003	-.9113		
27.50			-11.0700	-5.2713	-.7827		
30.00				-8.7025			
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A14

BINOCULAR ERRORS - POSITION 1 RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

CONVERGENCE/DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	50.0159	9.2058	7.0835	5.3326	4.3907	2.4039	11.3688
2.50	50.4398	9.4570	7.0332	5.4029	4.3975	2.4001	12.0727
5.00	50.9133	10.3024	6.9060	5.5748	4.4058	2.4447	14.4083
7.50		12.0299	6.7837	5.7540	4.3949	2.6923	19.2834
10.00		15.1674	6.8264	5.8564	4.3724	3.3657	
12.50		20.5026	7.2999	5.8936	4.4131	4.7564	
15.00		28.3984	8.6418	6.0451	4.6955	7.3250	
17.50			11.5773	6.6888	5.5185	12.0813	
20.00			16.8253	8.3740	7.2528		
22.50				11.4700			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A15

BINOCULAR ERRORS - POSITION 2 RAYS

CODE V 7/24/79

SINGLET REFERENCE

Position 2 - Position 1

DIVERGENCE
ANGULAR ERRORS (MILLIRAD)

ELEVATION (DEGREES)	AZIMUTH (DEGREES) -5.00	1.70	8.70	15.00	21.70	28.30	35.00
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	-3.3392	-.2963	-.2154	-.2963	-.1065	-.3434	.8689
5.00	-6.6527	-.7871	-.3366	-.5477	-.3274	-.6729	2.2088
7.50		-1.7632	-.3704	-.7208	-.6906	-.8839	4.7895
10.00		-3.7146	-.4905	-.8295	-1.0896	-.7516	
12.50		-7.4230	-1.0507	-.9778	-1.3362	.0550	
15.00		-13.5473	-2.6146	-1.3833	-1.2878	2.0580	
17.50			-6.1313	-2.4360	-.9129	6.5206	
20.00			-12.6767	-4.9050	-.2550		
22.50				-9.3392			
25.00							
27.50							
30.00							
32.50							
35.00							
37.50							
40.00							
42.50							
45.00							
47.50							
50.00							

Table A16

BINOCULAR ERRORS - POSITION 2 RAYS